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Plant-based dietary indices and stress in female college students: a cross-sectional study

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Abstract

Only a few studies have investigated the association between psychological stress and the healthfulness of plant-based diets while accounting for variances in age groups and regions. In light of this, this study aimed to identify the food groups that contribute the most to the relationship between the healthfulness of plant-based diets and psychological stress in female students in Saudi Arabia. This cross-sectional study, which included 401 female college students aged 19–35 years, collected data on blood, anthropometric indices, the perceived stress scale-10 (PSS-10) and diet using the Saudi food frequency questionnaire. An overall plant-based diet index (PDI), healthy PDI, and an unhealthy PDI (uPDI) were defined. Multiple linear regression analyses were applied to examine the associations between PSS-10 and PDI and hPDI and uPDI. No associations between the PSS-10 score and the overall PDI or uPDI scores were found; however, a six-point higher hPDI score was associated with a 0·16-point lower PSS-10 score (95 % CI, –0·24, –0·08) after controlling for lifestyle factors. Moreover, adjustments for healthy food groups, including vegetables and fruits, attenuated the association between the hPDI and PSS-10. In conclusion, healthy plant-based diets are associated with lower psychological stress in young Saudi women. This finding highlights the importance, especially for female students, of following diets that are not only plant-based but are also healthy and rich in fruits and vegetables.

Key words: Plant-based index: Healthy plant-based diet: Unhealthy plant-based diet: Perceived stress scale: Dietary habits: Mental health

Psychological stress is a negative affective condition in which environmental demands tax or exceed one's adaptive capacity[1]. A recent study of 329 adults in Saudi Arabia found that 47·7 % were experiencing stress, and rates were significantly higher among females[2]. In a larger study (*n* 1597) focusing on stress in Saudi Arabia during the coronavirus disease 2019 pandemic, 12 % of respondents reported moderate to severe stress levels, and it was significantly higher among females and younger participants[3]. Similarly, among young adults, particularly those attending university in Saudi Arabia, the prevalence of stress is evident, with results again indicating that female students experience higher stress levels than male students[4,5]. Moreover, this period between adolescence and adulthood is considered stress arousing in general, given that college students are in a transitional time wherein they are obtaining independence and self-sufficiency[6]. This is concerning given that high levels of stress are linked to other negative affective states, such as depression and anxiety, and can influence biological processes that increase susceptibility to chronic disease[1].

It is thought that nutrition can play an essential role in mental health and that dietary shifts towards less healthy dietary patterns may be detrimental[7]. Diets in Saudi Arabia are transitioning towards higher intakes of saturated fats, cholesterol and refined carbohydrates and lower intakes of polyunsaturated fats and fibre[8]. This is considered a Western dietary pattern and has been associated with higher levels of negative affective conditions[9]. However, investigations into the relationship between plant-based diets, including vegan and vegetarian diets, and the negative affective conditions have resulted in conflicting results. For instance, according to some studies, plant-based diets are associated with decreased levels of negative affective conditions, including stress[10,11], while other studies have not found such an association[12,13]. Two recent systematic reviews and meta-analyses attempted to address these inconsistencies[14,15]. Iguacel and colleagues[14] concluded that there were no associations between consuming a vegetarian diet, continuous depression scores or stress. Likewise, Askari and colleagues[15] found no relationship between a plant-based diet and either depression or anxiety and concluded that the available pooled data were insufficient

Abbreviations: hPDI, healthy PDI; hs-CRP, high-sensitivity C-reactive protein; PDIs, plant-based diet indices; PSS, perceived stress scale; uPDI, unhealthy PDI.

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to confirm the relationship between plant-based diets and psychological stress, highlighting the need for more research[15]. The adherence to plant-based diets in Saudi Arabia has not been thoroughly investigated. Only a couple of small cross-sectional studies related to disordered eating have examined the rates of vegetarianism among young women (between 7 % and 11 % of the study population)[16,17].

However, not all plant-based diets are of comparable quality. The discrepancies in previous findings may be due to variations in the healthfulness and completeness of these diets in providing necessary nutrients. Only a couple of studies have investigated the relationship between psychological stress and diet while accounting for differences in the healthfulness of plant-based diets[11,18]. These studies found that adherence to healthier plant-based diets was associated with reductions in psychological stress[11], while unhealthy plant-based diets were associated with increases in psychological stress[18]. Both studies used the Depression, Anxiety, and Stress Scale, a tool used to generate scores for general negative affective disorders[19]. Although depression, anxiety and stress are invariably related, they are distinct diagnoses that warrant individual and focused investigations. Furthermore, the relationship between plant-based diets and mental health has been shown to vary between countries[12], emphasising the importance of regionally specific studies, especially given the noticeable lack of evidence on these topics in Saudi Arabia. The aim of this study was to examine the relationship between the healthfulness of plant-based diets and psychological stress in female students in Saudi Arabia.

Methods

Study design

The current cross-sectional study involved a total of 401 college students aged 19–35 years from the female campus of King Saud University, Riyadh, Saudi Arabia. The details of the study design were published previously[20]. Briefly, a pilot study was initially carried out on thirty volunteers to standardise the methodology; the pilot study volunteers and their data were not part of the final study sample. Students were invited to take part in the study through the university's email directory, social media networks and ads. After students provided their consent, data were collected over a period of 4 months, with each participant providing demographic, dietary and anthropometric information at the clinics of the College of Applied Medical Sciences, King Saud University. Figure 1 shows the flow chart of the study. For biochemical analysis, blood samples were collected from the phlebotomy room of the same college. Students were excluded if they had been diagnosed with a chronic or inflammatory disease (e.g., CVD, diabetes mellitus, rheumatoid arthritis) or infection; were taking high dosages (> 300 mg/d) of any nonsteroidal anti-inflammatory medications (e.g., aspirin); were on hormonal contraceptives (e.g., birth control pills) or were pregnant (*n* 10). Participants had the right to withdraw consent at any time without offering any reason. This study was approved by the local institutional ethics committee of the specified site (reference number 19/0105/IRB).

Dietary assessment

A validated Saudi FFQ with high overall reproducibility[21] was administered by trained interviewers using a standardised protocol to collect data regarding individuals' food and beverage intake during the prior year. The Goldberg equation[22] was used to define under- and over-reporters of energy. Based on this equation, twenty-seven students were excluded from the analysis (total energy intake was < 650 or > 4200 kcal/d), bringing the total number of participants to 401. To validate the FFQ data, two 24-h dietary recalls were additionally used on 25 % of the participants (*n* 100). The FFQ comprised 133 food items and also collected data on fast food intake and the use of artificial sweeteners and added fats and salt. The USA Department of Agriculture food composition tables[23] were used to identify the nutritional content of foods. Dietary data were entered using NutriBase version 20 (CyberSoft Inc.).

Plant-based diet indices

Plant-based diet indices (PDIs) have been defined previously[24]. In brief, a PDI assigns positive scores to plant-based foods and negative scores to animal-based foods. The healthy PDI (hPDI) and unhealthy (uPDI) are versions of the overall PDI that are distinguished based on healthfulness. Therefore, for the hPDI, plant-based foods that are established as healthier were assigned positive scores (e.g. whole grains, fruits, vegetables, nuts and legumes, vegetable oils, tea and coffee). Less healthy plant foods were assigned negative scores (e.g. fruit juices, sugary drinks, refined grains, potatoes, sweets and desserts), as were animal-based food sources (e.g. dairy products, eggs, fish or shellfish and total meat) and miscellaneous food sources (e.g. hamburgers). Local foods were also added to each plant index, according to type. For the uPDI, less healthy plant-based food groups were given positive scores, and healthy plant-based and animal-based food sources were assigned negative scores.

The Saudi Dietary Guidelines[25] were used as references for each food group, where intakes equal to or above the guideline recommendations were identified as being in the highest quartile and given a score of 4 (online Supplementary Table S1). Afterwards, intakes below those of the guideline recommendations were divided into tertiles, and scores of 3 to 1 were assigned.

Scores from the plant-based indices were determined by summing the scores of all food groups (the maximum and minimum scores were 54 and 12, respectively). For the three indices, a high score means low intake of animal-based foods.

Blood biochemical test

Blood samples (2 ml) were withdrawn from each participant during the clinic visit. Plasma and serum were isolated via low-speed centrifugation and were frozen (–80°C). High-sensitivity C-reactive protein (hs-CRP) was measured using an enzyme-linked immunosorbent assay kit (Aviva Systems Biology, OKBA00016) according to the manufacturer's protocol. The hs-CRP assays were calibrated using international standards crafted by the Centers for Disease Control and Prevention. The hs-CRP was measured for 289 randomly selected participants, and duplicate runs for

British Journal of Nutrition

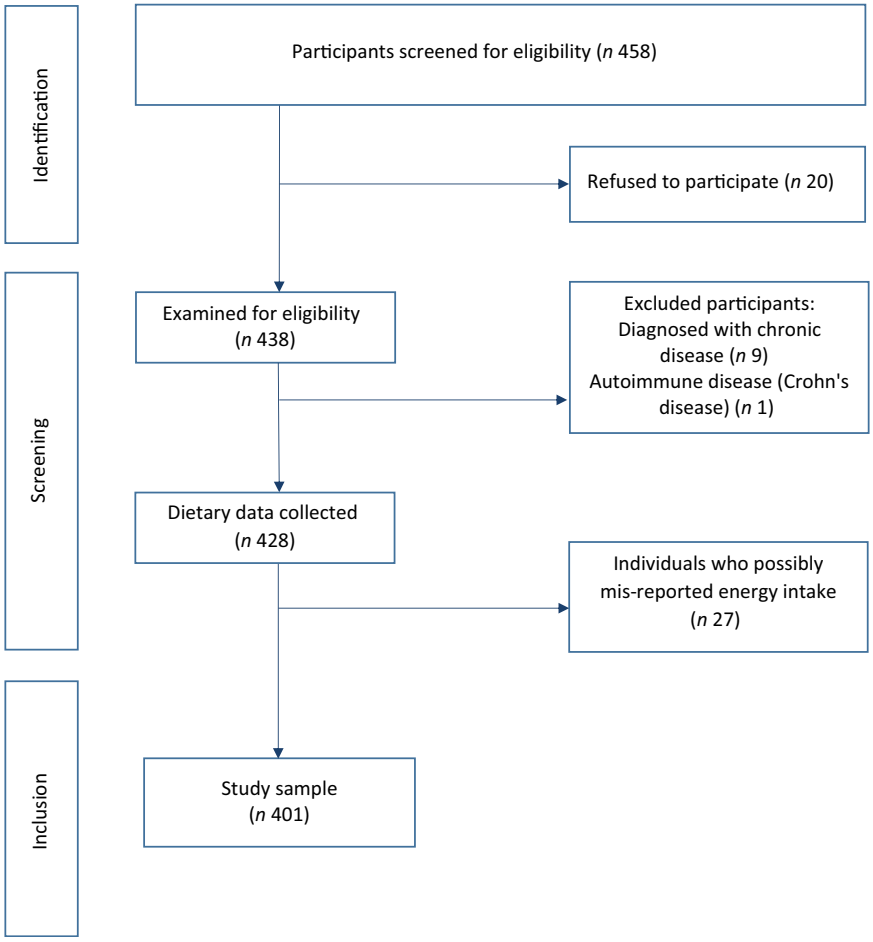

Fig. 1. Flow chart of study participants.

samples and standards were conducted. The cut-off values of hs-CRP were set as > 3·00 mg/l for a high risk of cardiovascular disease; 1·00–3·00 mg/l for a moderate risk and < 1·00 mg/l for a low risk.

Perceived stress scale

The perceived stress scale (PSS-10; Arabic version) was used to assess each participant's stress level. This is a validated stress-assessment tool with adequate psychometric properties of reliability and validity that can be applied to different populations[1]. The PSS-10 is composed of ten items and measures the prevalence of stressful incidences over the previous month on a five-point Likert scale that includes never (0), almost never (1), sometimes (2), fairly often (3) and very often (4). To sum the PSS-10, scores are reversed for select questions (4, 5, 7 and 8) such that 0 = 4, 1 = 3, 2 = 2, 3 = 1 and 4 = 0. Low, moderate and high levels of stress are defined as score tertiles of 4 – 17, 18 – 23 and 24–36, respectively.

Assessment of confounding variables

When the participants visited the clinic, trained interviewers collected data on demographic characteristics including age (continuous variable), marital status (single, married), education level (bachelor's, master's and PhD degree), duration of physical activity (min/d) and intensity of physical activity (low, moderate and severe) defined according to the Centers for Disease Control and Prevention and the American College of Sports Medicine guidelines[26], smoking (yes, no), family income per month (categorised according to the Saudi General Authority of Statistics[27], sleeping (h/d), medical history (presence of any medical condition refers to chronic constipation, gastroesophageal reflux disease, prolactinoma, vitamin D deficiency, polycystic ovary syndrome and hypothyroidism), previous use of a weight loss diet (yes, no) and medication use (yes, no).

Weight and height were recorded twice while participants were not wearing shoes or any heavy clothing. Weight was measured using a mechanical beam scale (Detecto) to the nearest 0·1 kg, and height was measured using a stadiometer (Detecto) to the nearest 0·1 cm. The BMI (kg/m^2) was calculated using the average of the two measures.

Statistical analysis

SAS version 9.4 (SAS Institute Inc.) was used for the analyses. The sample size was calculated assuming a stress level ranging between 45 and 65 %[4,5,28], with a margin of missing data set at 5 % and a confidence level of at least 95 %. The normality of each quantitative variable was tested before analysis using

the Kolmogorov–Smirnov test. Socio-demographic characteristics were presented by quartiles of PDI, hPDI and uPDI using the generalised linear age-adjusted model procedure in SAS for continuous variables, with type III SS *P*-value of 0·05 or less considered significant. Frequencies were used for categorical variables. The relation between PSS score, PDI indices, hs-CRP and anthropometrics was identified using Pearson partial correlation.

Multivariate linear regression models were applied to estimated the mean differences in the PSS-10 score with a six point (1 SD) higher score of PDI, hPDI and uPDI in participants. The models were adjusted for potential lifestyle confounders: age, marital status, education level, college, family income, medical condition, previous weight loss, sleeping h/d, duration of physical activity and BMI. Further adjustment for hs-CRP was included. Additional models were used to identify food groups that contribute the most to the relation between the PDI scores and PSS-10 by summing up the foods other than the intended variable to avoid over-adjusting (e.g. a variable summing up food groups other than fruits was added to the model when investigating the influence of fruits in the relation between PDI scores and PSS-10). *P* values < 0·05 were considered statistically significant.

Results

Characteristics

About (57 %) of participants were classified as moderately stressed and (30 %) as highly stressed with a mean PSS-10 score of 20·12 ± 6·13 (online Supplementary Table S2). Compared with participants with low hPDI scores, participants with high hPDI scores had higher incomes; spent more hours doing physical activity, especially high-intensity physical activity; had more body muscle; had lower BMIs; had lower body fat percentages; had lower hs-CRP (mg/l) levels and lower PSS-10 scores (Table 1).

In contrast, compared with participants with low uPDI scores, participants with high uPDI scores were less physically active; had higher BMIs; had higher hs-CRP (mg/l) levels and had dietary intakes rich in saturated fat and low in dietary fibre.

According to the analysis of the nutrient compositions of the scores, compared with lower hPDI scores, higher hPDI scores were lower in dietary cholesterol and higher in vitamin E, vitamin C, vitamin B_{12}, thiamine, dietary Ca, K and Mg (online Supplementary Table S3).

The partial correlation between the hPDI and uPDI scores was inverse ($r = -0·29$), while the scores on the overall PDI were positively correlated with hPDI scores ($r = 0·28$) and inversely correlated with uPDI scores ($r = -0·30$; Table 2). The PSS-10 scores were inversely correlated with the overall PDI scores ($r = -0·13$) and hPDI scores ($r = -0·10$) and were positively correlated with uPDI scores ($r = 0·10$) (Table 2).

Associations between perceived stress scale-10 and overall plant-based diet index and healthy plant-based diet index scores

A regression analysis revealed no association between the PSS-10 score and a six-point higher overall PDI score (model 2; Table 3). However, a six-point higher hPDI score was associated with a 0·16-point lower PSS-10 score (95 % confidence interval, –0·24, –0·08) after controlling for lifestyle factors. These results remained significant after adjusting for BMI. Further adjustment for hs-CRP attenuated the association between hPDI and PSS-10 and was no longer significant (model 3b, Table 3). Additional individual adjustments for healthy food groups attenuated the association between the hPDI and PSS-10 scores for vegetables and fruits (models 3c and 3d; Table 3). The data revealed no evidence of potential effect modification by BMI when using stratified analyses and interaction terms.

Association between perceived stress scale-10 score and ulhealthy plant-based diet index score

A six-point higher uPDI score was not associated with the PSS-10 score. The results were similar with adjustments for individual unhealthy food groups (Table 3).

Discussion

To date, studies focused on the associations between plant-based diets and negative affective disorders have found mixed results[14,15]. In this context, this study fills in an important and noted gap between the relationship between stress and plant-based diets[15]. This study's key findings were an inverse relationship between hPDI and stress and lower hs-CRP with higher adherence to an hPDI. The food groups that contributed most to the inverse association between stress and hPDI were fruits and vegetables.

This study found that higher adherence to an hPDI was associated with lower levels of stress. This finding is similar to other studies investigating the healthfulness of plant-based diets and negative affective disorders[11,18,29]. Using the Depression, Anxiety, and Stress Scale questionnaire in a sample of Iranian women, Zamani and colleagues[11] recently found inverse associations between higher overall PDI and hPDI scores and depression, anxiety and psychological distress and a positive association between uPDI scores and depression. Similarly, also using the Depression, Anxiety, and Stress Scale questionnaire in a sample of women with diabetes, Daneshzad and colleagues[18] found that those with the highest adherence to a uPDI had greater risks of depression, anxiety and stress. Likewise, using mental component scores, Baden and colleagues[29] found that higher overall PDI and hPDI scores were associated with mental health improvements. Results of the present study are also similar to those from investigations of plant-based diets more generally, which have demonstrated the benefits of vegan and vegetarian diets on symptoms of stress, depression and/or anxiety[10,30]. In addition, findings from other studies have indicated that the relationship between plant-based diets and stress may be moderated by gender[10], but whether this stems from biology or society remains unclear[31]. Unlike most previous literature investigating the relationship between stress and the healthfulness of plant-based diets, this study utilised the PSS-10 questionnaire, which is explicitly designed to measure stress. PSS-10 scores have been correlated with biomarkers of stress[32–34],

Table 1. Characteristics per quartiles of plant-based indices*
(Mean values and 95 % confidence intervals, *n* 401)

	Quartile 1			Quartile 2			Quartile 3			Quartile 4			
	Plant-based diet index												
	%	Mean	95 % CI	%	Mean	95 % CI	%	Mean	95 % CI	%	Mean	95 % CI	*P*
N	100			100			100			101			
Median PDI	40·0			41·0			43·0			44·0			
Age (years)		21·3	20·7, 21·9		21·5	20·9, 22·2		21·9	21·3, 22·6		21·9	21·3, 22·5	0·412
Marital status (%)													
Single	91·0			93·8			98·9			85·9			
Married	9·0			6·2			1·2			14·2			
Education level													
Bachelor's	93·7			91·8			83·9			86·8			
Master's	4·5			7·2			14·9			13·2			
PhD	1·8			1·0			1·2			0·0			
College													
Medical	49·6			38·1			34·5			34·0			
Non-medical	50·5			61·9			65·5			66·0			
Family income per month (SR)													
< 5000	7·2			5·2			3·5			2·8			
5000–< 10 000	29·7			21·7			24·1			22·6			
10 000–< 19 000	30·6			33·0			36·8			20·8			
≥ 19 000	32·4			40·2			35·6			53·8			
Sleeping h/d													
< 6 h	15·3			11·3			18·4			22·6			
6–7 h	43·2			40·2			37·9			36·8			
> 7–≤ 10 h	37·8			44·3			41·4			37·7			
> 10 h	3·6			4·1			2·3			2·8			
The presence of any medical condition†													
No	91·0			91·8			88·5			88·7			
Yes	9·0			8·3			11·5			11·3			
Previous weight loss diet													
No	59·5			63·9			65·5			64·2			
Yes	40·5			36·1			34·5			35·9			
The intensity of PA													
Low	36·9			39·2			33·3			30·2			
Moderate	55·9			53·6			59·8			62·3			
High	7·2			7·2			6·9			7·6			
Duration of PA (min/d)		59·4	51·3, 67·6		63·1	54·3, 71·8		64·0	54·8, 73·2		58·7	50·3, 67·0	0·794
BMI (kg/m^2)		23·3	22·2, 24·3		23·5	22·5, 24·4		25·0	24·1, 26·0		23·8	22·7, 24·8	0·052
Hs-CRP (mg/l)‡		2·5	1·7, 3·3		2·8	2·1, 3·5		2·9	2·2, 3·6		2·2	1·4, 3·0	0·532
PSS score-10		21·1	20·0, 22·3		19·7	18·5, 20·9		19·5	18·2, 20·8		20·0	18·8, 21·2	0·202
	Healthy plant-based diet index												
n	100			100			100			101			
Median hPDI	36·0			40·0			44·0			49·0			
Age (years)		21·1	20·4, 21·7		21·9	21·3, 22·5		21·7	21·1, 22·3		22·0	21·4, 22·6	0·183
Marital Status (%)													
Single	93·8			91·4			94·4			88·2			
Married	6·3			8·6			5·6			11·8			
Education level													

Table 1. (*Continued*)

	Quartile 1			Quartile 2			Quartile 3			Quartile 4			
	Plant-based diet index												
	%	Mean	95 % CI	%	Mean	95 % CI	%	Mean	95 % CI	%	Mean	95 % CI	*P*
Bachelor's	91·7			89·5			86·9			89·3			
Master's	8·3			9·5			11·2			9·7			
PhD	0·0			1·0			1·9			1·1			
College													
Medical	36·5			43·8			36·5			40·9			
Non-medical	63·5			56·2			63·6			59·1			
Family income per month (SR)													
< 5000	5·2			4·8			5·6			3·2			
5000–< 10 000	25·0			21·9			24·3			28·0			
10 000–< 19 000	31·3			34·3			29·9			23·7			
≥ 19 000	38·5			39·1			40·2			45·2			
Sleeping h/d													
< 6 h	11·5			18·1			16·8			21·5			
6–7 h	38·5			38·1			40·2			41·9			
> 7–≤ 10 h	46·9			37·1			40·2			36·6			
> 10 h	3·1			6·7			2·8			0·0			
The presence of any medical condition†													
No	87·5			92·4			87·9			92·5			
Yes	12·5			7·6			12·2			7·5			
Previous weight loss diet													
No	72·9			64·8			57·9			57·0			
Yes	27·1			35·2			42·1			43·0			
The intensity of PA													
Low	38·5			37·1			33·6			30·1			
Moderate	57·3			53·3			63·6			57·0			
High	4·2			9·5			2·8			12·9			
Duration of PA (min/d)		55·8	47·0, 64·5		56·6	48·3, 64·9		61·9	53·7, 70·2		70·7	61·9, 79·5	0·072
BMI (kg/m²)		25·6	24·6, 26·5		23·4	22·4, 24·4		23·3	22·2, 24·3		23·1	22·1, 24·0	< 0·0001
Hs-CRP (mg/l)‡		3·4	2·7, 4·1		2·7	1·9, 3·4		1·9	1·0, 2·7		2·3	1·6, 3·1	0·032
PSS score-10		21·0	19·8, 22·2		20·4	19·3, 21·6		20·8	19·7, 22·0		18·0	16·7, 19·2	< 0·01
	Unhealthy plant-based diet index												
n	100			100			100			101			
Median uPDI	34·0			40·0			45·0			49·0			
Age (years)		21·5	20·8, 22·1		21·5	20·8, 22·1		22·2	21·5, 22·8		21·6	20·9, 22·1	0·334
Marital Status (%)													
Single	91·4			90·7			90·0			95·5			
Married	8·6			9·4			10·0			4·5			
Education level													
Bachelor's	92·5			88·8			85·6			90·1			
Master's	7·5			10·3			13·3			8·1			
PhD	0·0			0·9			1·1			1·8			
College													
Medical	40·9			41·1			36·7			38·7			
Non-medical	59·1			58·9			63·3			61·3			
Family income per month (SR)													
< 5000	4·3			2·8			6·7			5·4			
5000–< 10 000	19·4			29·9			27·8			21·6			

Table 1. (*Continued*)

	Quartile 1			Quartile 2			Quartile 3			Quartile 4			
	Plant-based diet index												
	%	Mean	95 % CI	%	Mean	95 % CI	%	Mean	95 % CI	%	Mean	95 % CI	*P*
10 000–< 19 000	32·3			25·2			26·7			35·1			
≥ 19 000	44·1			42·1			38·9			37·8			
Sleeping h/d													
< 6 h	21·5			15·9			14·4			16·2			
6–7 h	33·3			43·0			48·9			34·2			
> 7–≤ 10 h	41·9			39·3			33·3			45·1			
> 10 h	3·2			1·9			3·3			4·5			
The presence of any medical condition†													
No	90·3			90·7			91·1			88·3			
Yes	9·7			9·4			8·9			11·7			
Previous weight loss diet													
No	50·5			64·5			58·9			75·7			
Yes	49·5			35·5			41·1			24·3			
The intensity of PA													
Low	26·9			27·1			42·2			43·2			
Moderate	60·2			63·6			53·3			54·1			
High	12·9			9·4			4·4			2·7			
Duration of PA (min/d)		70·7	61·9, 79·4		68·6	60·5, 76·8		48·6	39·7, 57·5		55·9	47·9, 63·9	< 0·0001
BMI (kg/m²)		23·1	22·1, 24·1		23·1	22·1, 24·0		24·7	23·7, 25·8		24·7	23·7, 25·6	0·023
Hs-CRP (mg/l)‡		2·3	1·5, 3·2		2·3	1·6, 3·1		3·1	2·3, 3·9		3·5	2·7, 4·4	0·042
PSS-10 score		20·0	18·7, 21·2		19·9	18·7, 21·1		20·4	19·2, 21·7		20·2	19·1, 21·4	0·922

hPDI, healthy plant-based diet index; hs-CRP, high-sensitivity C-reactive protein; PA, physical activity; PDI, plant-based diet index; PSS-10, perceived stress scale; SR, Saudi riyals; uPDI, unhealthy plant-based diet index.
* Values are mean (95 % CI) or %.
† Medical condition refers to (chronic constipation, gastroesophageal reflux disease, prolactinoma, vitamin D deficiency, polycystic ovary syndrome and hypothyroidism).
‡ hs-CRP was collected from 289 participants.

Table 2. Pearson partial correlation between high-sensitivity C-reactive protein, perceived stress scale score, plant-based diet index indices and anthropometrics, *n* 401*

Variable	PSS score	hs-CRP	PDI	hPDI	uPDI
PSS-10 score	1·00	0·51	−0·13	−0·10	0·10
PDI	−0·13	−0·13	1·00	0·28	−0·30
hPDI	−0·10	−0·22	0·28	1·00	−0·29
uPDI	0·10	0·17	−0·30	−0·29	1·00
BMI	0·30	0·41	−0·20	−0·16	0·19

* Correlations were significant between ($r = 0{\cdot}10$, $-0{\cdot}10$).

Table 3. Estimated mean differences in perceived stress scale-10 score with a six point (1 SD) higher score of plant-based diet indice, healthy plant-based diet indice and unhealthy plant-based diet indice in study participants*,†
(Mean values and standard errors, *n* 401)

	PSS-10 score		
	Mean	95 % CIs	*P*
PDI			
Model 1	−0·06	−0·14, 0·02	0·135
Model 2	−0·06	−0·13, 0·02	0·203
Model 3a	−0·03	−0·11, 0·05	0·503
hPDI			
Model 1	−0·14	−0·22, −0·05	< 0·01
Model 2	−0·16	−0·24, −0·08	< 0·001
Model 3a	−0·17	−0·25, −0·08	< 0·0001
Model 3b	−0·03	−0·29, 0·25	0·803
Model 3c	−0·19	−0·51, 0·21	0·582
Model 3d	−0·18	−0·57, 0·24	0·601
uPDI			
Model 1	0·04	−0·06, 0·15	0·400
Model 2	0·05	−0·05, 0·16	0·301
Model 3a	0·03	−0·06, 0·13	0·532

hPDI, healthy plant-based diet index; PDI, plant-based diet index; PSS-10, perceived stress scale; SD, standard deviation; uPDI, unhealthy plant-based diet index.
* Values are presented as means (95 % CIs).
† Model 1 is a crude (unadjusted) model. Model 2 is adjusted for age, marital status, education level, college, family income, medical condition, previous weight loss, sleeping h/d and duration of physical activity. Model 3a is model 2 adjusted for BMI. Model 3b is model 2 adjusted for hs-CRP. Model 3c is model 2 adjusted for intakes of fruits and 'sum of food groups other than fruits'. Model 3d is model 2 adjusted for intake of vegetables and 'sum of food groups other than vegetables'.

and the use of the PSS-10 has often been evaluated among college students[35].

Other research has demonstrated rates of stress similar to those observed in the present study. Studies conducted in Saudi Arabia suggest that 47·7 % of participating adults experienced stress, with 12 % experiencing moderate to severe stress[2,3]. Other studies of university students in Saudi Arabia have found that rates of stress among females were as high as 48·6 % to 75·7 % among medical students and 38·7 % among non-medical students[4,5]. Research investigating the prevalence of stress among university students in other countries has found similar results. For instance, 59·6 % and 51·9 % of the female medical and non-medical university students participating in studies in India and Turkey, respectively, experienced stress[36,37].

Hs-CRP is considered an independent risk factor for CVD and is an important health measure to consider[38], and associations between hPDI and stress attenuated when adjusted for hs-CRP. It is thought that psychosocial factors, such as psychological stress, can influence CVD processes, including inflammation[39]. The present study found that hs-CRP levels were lower in participants with higher adherence to an hPDI and lower adherence to a uPDI. These findings concur with that of Baden and colleagues, who found hPDI scores were inversely related to hs-CRP in cross-sectional and longitudinal analyses, and uPDI was positively associated with changes in hs-CRP in longitudinal analyses[40].

Plant-based foods considered healthy in the PDI score include whole grains, fruits, vegetables, nuts, legumes, vegetable oils, tea and coffee. The present study found that fruits and vegetables positively contributed to the inverse association between stress and hPDI scores. This finding is similar to results from other investigations into plant-based diets and stress[10] and concurs with studies demonstrating that fruits and vegetables are associated with lower odds of or improved psychological distress[41–43]. Several mechanisms are thought to mediate the relationship between fruit and vegetable intakes and psychological well-being[44], including a slow release of glucose, which results in the stimulation of serotonin, and the provision of B_6, folate and certain minerals, which have been shown to impact neurotransmitter synthesis and improve brain function and processing[44,45]. Additionally, plant-based foods, including fruits and vegetables, are an important source of antioxidants, which are posited to reduce oxidative stress and inflammation, that can be detrimental to psychological well-being[44,45].

Nutrients such as vitamin B_{12}[46] and vitamin D[47] have also been studied regarding psychological well-being, with low levels and deficiencies being associated with depression. However, animal products are a major source of these nutrients, with vitamin B_{12} found in fish, meats, eggs and milk[48] and vitamin D found in fish, meats, eggs and fortified foods[49]. Thus, there are some concerns that consuming an entirely plant-based diet might lead to nutrient deficiencies of dietary components associated with mental health[50,51]. However, when examined in terms of stress levels, the present study's findings do not suggest deficiencies in those participants following a plant-based diet. The nutrient compositions of the scores revealed that a higher hPDI was higher in vitamin B_{12} and a higher uPDI was lower in vitamin D. Furthermore, the nature of the PDI scoring does not require complete abstention from animal products, although a higher PDI score does result from a higher proportion of plant-based sources in the diet.

Meanwhile, those with higher uPDI scores had higher intakes of sugary drinks and sweets. Similarly, sweet intake in other studies was positively related to stress and anxiety in females[52–54]. In fact, according to a recent cross-sectional study in Saudi Arabia, the perceived stress among females led to an increased preference for sweets[52]. Furthermore, Western dietary patterns, characterised in part by the consumption of high-energy, low-nutrient dense foods, such as sweets and sugary drinks, have been associated with higher levels of negative affective conditions[8].

The current study has several strengths. It used assessment tools, such as the FFQ and PSS-10, that are validated, interview-based, and follow thorough and rigorous protocols. Measurement of hs-CRP provided an objective standard for evaluating inflammation. As per WHO guidelines, all measurements were recorded twice and the average was used for analyses; however, residual confounding due to measurement error is

possible. In addition, the temporal nature of the association between plant-based diets and stress cannot be determined with a cross-sectional study. It could be that stress leads to the consumption of less healthy diets or that healthier diets lead to reduced stress. Moreover, misreporting of energy is unavoidable, although efforts were made to ensure accurate dietary data, including through the use of the Goldberg cut-off values and validation with 24-h recalls of 20 % of the total FFQ. On the other hand, the use of hs-CRP as a marker of inflammation has its limitations. For instance, hs-CRP measures were taken only once, which does not account for variations in measurements over time[55,56]

In conclusion, this study found that healthy plant-based diets are associated with lower levels of psychological stress in young Saudi Arabian students. This finding underscores the importance of following diets that are not only plant-based but are also healthy, especially among female students, given that the relationship with stress is thought to be mediated by gender.

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I declare no conflict of interest.

Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S0007114521001689

References

1. Cohen SKR & Gordon LU (1995) *Strategies for Measuring Stress in Studies of Psychiatric and Physical Disorder. Measuring stress: A Guide for Health and Social Scientists*. New York: Oxford University Press.
2. El-Gamal FM, Nadhrah HM, Abdulghani AA, *et al.* (2021) Depression, anxiety, stress and its determinant factors, among adult population in Jeddah, Saudi Arabia. Middle East. *J Fam Med* **19**, 18–25.
3. Alamri HS, Algarni A, Shehata SF, *et al.* (2020) Prevalence of depression, anxiety, and stress among the general population in Saudi Arabia during COVID-19 pandemic. *Int J Environ Res Public Health* **17**, 9183.
4. Abdulghani HM, AlKanhal AA, Mahmoud ES, *et al.* (2011) Stress and its effects on medical students: a cross-sectional study at a college of medicine in Saudi Arabia. *J Health Popul Nutr* **29**, 516–522.
5. Al-Sowygh ZH (2013) Academic distress, perceived stress and coping strategies among dental students in Saudi Arabia. *Saudi Dent J* **25**, 97–105.
6. Zirkel S & Cantor N (1990) Personal construal of life tasks: those who struggle for independence. *J Pers Soc Psychol* **58**, 172–185.
7. Freeman MP (2010) Nutrition and psychiatry. *Am J Psychiatr* **167**, 244–247.
8. Musaiger AO (2011) Overweight and obesity in eastern mediterranean region: prevalence and possible causes. *J Obes* **2011**, 407237.
9. Jacka FN, Pasco JA, Mykletun A, *et al.* (2010) Association of Western and traditional diets with depression and anxiety in women. *Am J Psychiatr* **167**, 305–311.
10. Beezhold B, Radnitz C, Rinne A, *et al.* (2015) Vegans report less stress and anxiety than omnivores. *Nutr Neurosci* **18**, 289–296.
11. Zamani B, Daneshzad E, Siassi F, *et al.* (2020) Association of plant-based dietary patterns with psychological profile and obesity in Iranian women. *Clin Nutr* **39**, 1799–1808.
12. Lavallee K, Zhang XC, Michalak J, *et al.* (2019) Vegetarian diet and mental health: cross-sectional and longitudinal analyses in culturally diverse samples. *J Affect Disord* **248**, 147–154.
13. Michalak J, Zhang XC & Jacobi F (2012) Vegetarian diet and mental disorders: results from a representative community survey. *Int J Behav Nutr Phys Act* **9**, 67–77.
14. Iguacel I, Huybrechts I, Moreno LA, *et al.* (2020) Vegetarianism and veganism compared with mental health and cognitive outcomes: a systematic review and meta-analysis. *Nutr Rev* **79**, 361–381.
15. Askari M, Daneshzad E, Darooghegi Mofrad M, *et al.* (2020) Vegetarian diet and the risk of depression, anxiety, and stress symptoms: a systematic review and meta-analysis of observational studies. *Crit Rev Food Sci Nutr* 1–11 doi: 10.1080/10408398.2020.1814991.
16. Fatima W, Fatima R & Anwar N (2018) Subclinical eating disorders and association with vegetarianism in female students of Saudi Arabia: a crosssectional study. *J Nurs Health Sci* **7**, 62–67.
17. Fatima W & Ahmad LM (2018) Prevalence of disordered eating attitudes among adolescent girls in Arar City, Kingdom of Saudi Arabia. *Health Psychol Res* **6**, 7444.
18. Daneshzad E, Keshavarz SA, Qorbani M, *et al.* (2020) Association of dietary acid load and plant-based diet index with sleep, stress, anxiety and depression in diabetic women. *Br J Nutr* **123**, 901–912.
19. Lovibond PF & Lovibond SH (1995) The structure of negative emotional states: comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. *Behav Res Ther* **33**, 335–343.
20. Alfreeh L, Abulmeaty MMA, Abudawood M, *et al.* (2020) Association between the inflammatory potential of diet and stress among female college students. *Nutrients* **12**, 2389.
21. Gosadi IM, Alatar AA, Otayf MM, *et al.* (2017) Development of a Saudi Food Frequency Questionnaire and testing its reliability and validity. *Saudi Med J* **38**, 636–641.
22. Food and Agriculture Organization of the United Nations (2001) *Human Energy Requirements: Report of a Joint FAO/WHO/ONU Expert Consultation*. Rome: Food and Agriculture Organization of the United Nations.
23. United States Department of Agriculture National Nutrient Database for Standard Reference. The National Agricultural Library (2019) Release 27. Software v.2.0b. Internet: http://ndb.nal.usda.gov/ndb/ (accessed October 2020).
24. Satija A, Bhupathiraju SN, Spiegelman D, *et al.* (2017) Healthful and unhealthful plant-based diets and the risk of coronary heart disease in US Adults. *J Am Coll Cardiol* **70**, 411–422.
25. The Saudi General Directorate of Nutrition & Ministry of Health (2012) Dietary Guidelines for Saudis 2012: The healthy Food Palm. Riyadh, Saudi Arabia. https://www.moh.gov.sa/en/Ministry/MediaCenter/Publications/Documents/ (accessed August 2020).
26. Pate RR, Pratt M, Blair SN, *et al.* (1995) Physical activity and public health. A recommendation from the Centers for Disease

Control and Prevention and the American College of Sports Medicine. *JAMA* **273**, 402–407.
27. General Authority of Statistics (2018) Kingdom of Saudi Arabia. https://www.stats.gov.sa/en (accessed September 2020).
28. Al-Daghri NM, Al-Othman A, Albanyan A, *et al.* (2014) Perceived stress scores among Saudi students entering universities: a prospective study during the first year of university life. *Int J Environ Res Public Health* **11**, 3972–3981.
29. Baden MY, Kino S, Liu X, *et al.* (2020) Changes in plant-based diet quality and health-related quality of life in women. *Br J Nutr* **124**, 960–970.
30. Beezhold BL & Johnston CS (2012) Restriction of meat, fish, and poultry in omnivores improves mood: a pilot randomized controlled trial. *Nutr J* **11**, 9.
31. Davis MC, Matthews KA & Twamley EW (1999) Is life more difficult on Mars or Venus? A meta-analytic review of sex differences in major and minor life events. *Ann Behav Med* **21**, 83.
32. Van Eck MM & Nicolson NA (1994) Perceived stress and salivary cortisol in daily life. *Ann Behav Med* **16**, 221–227.
33. Malarkey WB, Pearl DK, Demers LM, *et al.* (1995) Influence of academic stress and season on 24-hour mean concentrations of ACTH, cortisol, and β-endorphin. *Psychoneuroendocrinology* **20**, 499–508.
34. Beezhold BL, Johnston CS & Daigle DR (2010) Vegetarian diets are associated with healthy mood states: a cross-sectional study in seventh day adventist adults. *Nutr J* **9**, 26.
35. Lee E-H (2012) Review of the psychometric evidence of the perceived stress scale. *Asian Nurs Res* **6**, 121–127.
36. Iqbal S, Gupta S & Venkatarao E (2015) Stress, anxiety & depression among medical undergraduate students & their socio-demographic correlates. *Indian J Med Res* **141**, 354.
37. Bayram N & Bilgel N (2008) The prevalence and socio-demographic correlations of depression, anxiety and stress among a group of university students. *Soc Psychiatry Psychiatr Epidemiol* **43**, 667–672.
38. Lagrand WK, Visser CA, Hermens WT, *et al.* (1999) C-reactive protein as a cardiovascular risk factor: more than an epiphenomenon? *Circulation* **100**, 96–102.
39. Wirtz PH & von Känel R (2017) Psychological stress, inflammation, and coronary heart disease. *Curr Cardiol Rep* **19**, 111–121.
40. Baden MY, Satija A, Hu FB, *et al.* (2019) Change in plant-based diet quality is associated with changes in plasma adiposity-associated biomarker concentrations in women. *J Nutr* **149**, 676–686.
41. Richard A, Rohrmann S, Vandeleur CL, *et al.* (2015) Associations between fruit and vegetable consumption and psychological distress: results from a population-based study. *BMC Psychiatr* **15**, 213–221.
42. Nguyen B, Ding D & Mihrshahi S (2017) Fruit and vegetable consumption and psychological distress: cross-sectional and longitudinal analyses based on a large Australian sample. *BMJ Open* **7**, e014201.
43. McMartin SE, Jacka FN & Colman I (2013) The association between fruit and vegetable consumption and mental health disorders: evidence from five waves of a national survey of Canadians. *Prev Med* **56**, 225–230.
44. Rooney C, McKinley MC & Woodside JV (2013) The potential role of fruit and vegetables in aspects of psychological well-being: a review of the literature and future directions. *Proc Nutr Soc* **72**, 420–432.
45. Parletta N, Milte CM & Meyer BJ (2013) Nutritional modulation of cognitive function and mental health. *J Nutr Biochem* **24**, 725–743.
46. Coppen A & Bolander-Gouaille C (2005) Treatment of depression: time to consider folic acid and vitamin B_{12}. *J Psychopharmacol* **19**, 59–65.
47. Anglin RE, Samaan Z, Walter SD, *et al.* (2013) Vitamin D deficiency and depression in adults: systematic review and meta-analysis. *Br J Psychiatr* **202**, 100–107.
48. National Institutes of Health Vitamin B12: Fact Sheet for Health Professionals (2020) https://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/ (accessed October 2020).
49. National Institutes of Health Vitamin D: Fact Sheet for Health Professionals (2020) https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#h3. (accessed August 2020).
50. McEvoy CT, Temple N & Woodside JV (2012) Vegetarian diets, low-meat diets and health: a review. *Public Health Nutr* **15**, 2287–2294.
51. Craig WJ & Mangels AR (2009) Position of the American Dietetic Association: vegetarian diets. *J Am dietetic Assoc* **109**, 1266–1282.
52. Mohamed BA, Mahfouz MS & Badr MF (2020) Food selection under stress among undergraduate students in riyadh, saudi arabia. *Psychol Res Behavior Manag* **13**, 211–221.
53. Zellner DA, Loaiza S, Gonzalez Z, *et al.* (2006) Food selection changes under stress. *Physiol Behav* **87**, 789–793.
54. Yannakoulia M, Panagiotakos DB, Pitsavos C, *et al.* (2008) Eating habits in relations to anxiety symptoms among apparently healthy adults. A pattern analysis from the ATTICA Study. *Appetite* **51**, 519–525.
55. Koc M, Karaarslan O, Abali G, *et al.* (2010) Variation in high-sensitivity C-reactive protein levels over 24 h in patients with stable coronary artery disease. *Tex Heart Inst J* **37**, 42.
56. Bower JK, Lazo M, Juraschek SP, *et al.* (2012) Within-person variability in high-sensitivity C-reactive protein. *Arch Intern Med* **172**, 1519–1521.

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